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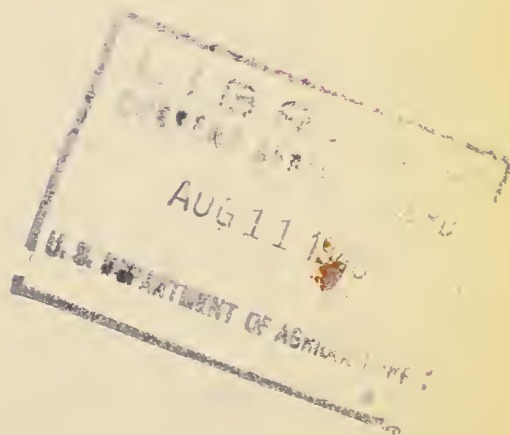
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Bulk Handling Vats and Infection Due to Bacterial
Soft Rot in Kern County, California, 1947. X

By

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D. H. Dewey, Assistant Physiologist

Fresno, California
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The Relationship Between Submerging Potatoes in
Bulk Handling Vats and Infection Due to Bacterial
Soft Rot in Kern County, California, 1947.

A new method of handling potatoes used in Kern County, California, in 1946 which eliminated the handling and dumping of field sacks at the packing shed was claimed by carlot receivers to be responsible for heavy transit losses of the tubers due to "breakdown". The potatoes were bulk-hauled from the field in trucks and trailers and dumped mechanically into large vats of water at the packing sheds. The poor condition of the tubers upon arrival at market was apparently due to their submersion in or removal from the water, because this treatment was the only essential divergence from the handling method previously used. The bulk-handling vats were 8 to 12 feet in depth and of sufficient capacity to hold several truck or trailer loads at once. They were constructed with the sides sloping to the bottom to feed an elevating conveyor connecting the vat to the grading belt (figure 1). The vats were filled with water and the potatoes dumped directly into them by lifting one side of the truck as shown in figure 2.

Upon recognizing the vat handling method as a source of trouble, many packing shed operators discontinued its use and reverted to the old method of hauling the potatoes to the shed in field sacks and dumping them manually onto the washing and grading conveyor. A few operators continued to use the bulk method but decreased the capacity of the vats by installing dummy walls which increased the pitch of the sloping surfaces to insure a better flow of tubers to the elevator, and chlorinated the water to reduce contamination. They also made a practice of emptying the vats of tubers and water at least once during each day of operation.

Literature Review:

A review of the literature indicates that if the "breakdown" of tubers occurring in the 1946 shipments was bacterial soft rot, the submersion of the potatoes in vats of water was probably a contributing factor in making it of serious consequence. Ruehle (5) ^{1/} found that washing water spreads the inoculum causing bacterial soft rot of potatoes and furnishes the moisture necessary for growth of the bacteria (*Erwinia carotovora*), and that washing the tubers in tubs was more

^{1/} Numbers in parentheses refer to Literature Citations.

Results:

A preliminary test to indicate the effect of different pressures and lengths of time of submersion on the incidence of bacterial soft rot in potatoes grown in Kern County was made early in the season. Tubers of size B which had been handled in sacks, washed and graded for shipment were obtained from a commercial house. Those with serious cuts, bruises or other mechanical injury were discarded and the rest were divided into lots of 15 tubers for treatment. The tubers were placed in two-quart jars, covered with tap water, water containing inoculum or water taken from a commercial potato washing vat and placed in the autoclaves for pressure treatment. The check tubers were washed in tap water, but otherwise were treated the same as the others.

The treatments are outlined in the following table together with the resulting amount of infection as indicated by number of infected tubers after incubation for 14 days.

Treatment Solution	Hydrostatic Pressure, lbs. per square inch	Time Submerged in Minutes	No. of infected Tubers (15 tubers treated)
Tap water	5	60	8
Do.	0	60	7
Do.	5	30	8
Do.	0	30	9
Washing vat	5	60	4
Do.	0	60	5
Do.	5	30	10
Do.	0	30	6
Inoculum	5	60	11
Do.	0	60	10
Do.	5	30	13
Do.	0	30	7
Check (washed in tap water)	--	--	2

Even though the bacterial soft rot was slow in appearing on these tubers in spite of the relatively high temperature and humidity of the incubation chamber, it was eventually definite enough to show that submersion for 30 minutes or longer in water favored infection in comparison to washing only. However, the samples were small and not replicated so the results are presented only as a supplement to later tests.

A second laboratory test was set up to compare the effect of zero pressure and five pounds pressure on injured and non-injured tubers in respect to soft rot infection. A sufficient number of size B tubers to provide 100-tuber lots for four replications of each treatment were selected, and treated in metal containers. These tubers were handled from the field in burlap sacks and were washed and graded in the ordinary commercial manner at the Bryant Smith shed at Edison, California.

Heat injury was produced by spreading the tubers on a greenhouse bench for four hours. They were in the direct rays of the sun and temperatures of 100 to 105 degrees F. were measured at their centers. Other tubers were mechanically injured by scraping one side over a vegetable grater in such a manner as to make wounds approximately one inch in length (figure 3). These tubers, together with uninjured ones, were covered with a water suspension of bacterial soft rot inoculum for one hour and subjected to zero pressure and a pressure of five pounds per square inch to simulate the surface and ten-foot depths of a bulk handling vat filled with water. The check treatment consisted of covering uninjured potatoes with tap water for one hour at zero pounds pressure.

The tubers were then placed in moistened burlap sacks, stacked and covered with moistened burlap in the incubation room. The lots were sorted periodically and the infected tubers removed when definite infection was in evidence. The test was discontinued the sixth day of incubation.

The results of this test are summarized in table 1. The accumulated number of infected potatoes are presented as percentage of the total number of tubers in each lot. The data were transformed from percentage to angle by the formula, $\text{angle} = \text{arc sin } \sqrt{\text{percentage}}$ (7) and subjected to the analysis of variance.

By comparing the percentage of rot infection between lots of potatoes subjected to zero and five pounds per square inch pressure it may be seen that hydrostatic pressure is of definite influence, provided the tubers have not been otherwise predisposed to soft rot infection by exposure to high temperatures. In the uninjured lots, the mean percentage of potatoes with soft rot increased from 2.2 percent to 23.3 percent, as the pressure was raised from zero to five pounds, and a similar wide and positive difference resulted from pressure differences in the mechanically injured treatments.

The influence of type of injury inflicted upon the tubers is profound. As has been reported by other workers (3,4,5), new and freshly dug potatoes may be quickly injured by exposure to sun and heat if the temperature of the potato tissues reaches 100°F. or higher when they are readily susceptible to soft rot infection. In these tests, the greatest amount of soft rot occurred in the heat-injured tubers and the effect of this injury overshadowed the effect of pressure. The percentage infected was higher in those lots subjected to zero pounds pressure than to five pounds. The tubers mechanically injured with a potato grater had significantly less infection than those which were either not injured or were subjected to sunlight and high temperatures. Some packing shed operators have expressed the view that the increased mechanical injury in bulk handling was responsible for the increase in decay over those handled in the customary way, but this view is not borne out by the results of this test. In fact, there are strong indications that increased mechanical injury decreased the incidence of soft rot infection. It has been known for some time (2) that

potato tubers respire more rapidly after being injured and that this condition may continue for several days. The increase in rate is attributed to several factors, particularly the facilitation of gaseous exchange, the response of the cell protoplasm to the stimulus of contact with oxygen of the air and to chemical changes, especially increases in sugars near the wounded area. Whether or not these have a relationship to the decreased infection noted in these tests is not known.

The tubers given the check treatment were handled the same as those of the treatment "Uninjured, zero pounds pressure" (table 1) in every respect with the exception of the solution in which they were submerged. The checks were covered with tap water and 1.9 percent of the tubers became infected, whereas the other tubers were covered with a tap water suspension of soft rot bacteria and showed a final infection of 2.2 percent. The difference between treatments is not significant and indicates that inoculum from sources other than the tuber is not a factor determining infection. That the soft rot organism occurs in the soils in all potato growing areas and is universally present on the tubers when harvested is commonly known.

As a supplement to the check treatment in the laboratory studies described above, treatments of zero and five pounds pressure for one hour were applied to tubers in tap water alone. As before, four 100-tuber lots were treated at each pressure and incubated in a similar manner. The mean percentage of total tubers infected after four days for those receiving five pounds pressure was $46.25 \pm 1.1 \frac{2}{\%}$ percent and for zero pounds, $7.75 \pm 2.59 \frac{2}{\%}$ percent. The mean difference between the two treatments amounts to 38.50 percent with a standard error of 2.84 percent. Application of the "t" test shows the odds against the difference as being due to chance to be considerably in excess of 99.1. As was true in the previous test, a hydrostatic pressure of five pounds greatly increased the incidence of soft rot infection over zero pounds. It is evident that these tubers carried sufficient bacteria to cause extensive inoculation and that another source of inoculum was not necessary to bring about serious rot.

Field Tests

The necessity of verifying the results of the laboratory studies was apparent, and for that purpose further experiments were conducted at the Rootes and Ohanneson potato shed at Shafter, California. A vat used commercially for bulk handling was available for submersion tests, and comparisons of soft rot infection in tubers held at different depths were possible.

2/ Standard error of the mean.



Materials and methods:

Size B potatoes of the variety White Rose which had been handled in 50-pound bags, washed, graded and prepared for commercial shipment were used for this study. Four 50-pound lots of tubers were weighed and bagged for each treatment and four or five tubers seriously infected with bacterial soft rot were added to each lot except those to be held as checks. The bulk handling vat was filled with fresh water (temperature 76°F.) and the tubers were submerged and treated simultaneously as follows:

- (1) One hour just below the water surface at an average depth of approximately one foot.
- (2) One hour at an average depth of five feet of water.
- (3) One hour at an average depth of ten feet of water.
- (4) One-half hour at an average depth of ten feet of water.
- (5) Check, tubers dipped at water surface until thoroughly wet to simulate ordinary washing.

The four lots of each treatment were then removed from the vat and the tubers added as a source of inoculum were removed. The potatoes were loaded into a closed body truck, covered with moistened burlap and hauled to the laboratory at Fresno where they were stacked at random in the incubation room and covered with moistened burlap. Final counts of the tubers definitely infected with bacterial soft rot were determined the third day of incubation. The data were converted to percentage of diseased tubers on the basis of total tubers per replication and transformed to angle by the formula, $\text{angle} = \text{arc sin} \sqrt{\text{percentage}}$, for statistical treatment by the analysis of variance.

Results:

Upon inspection of the potatoes after two days incubation, marked differences in the percentage of tubers infected with soft rot were noted. The number of tubers used for each replication and the mean percentage of total tubers infected with soft rot are given in table 2 together with the transformed means and their statistical comparison.

The outstanding fact to be noted is that the check treatment had significantly less soft rot than the other treatments. The tubers submerged for one hour at either one foot or five feet had twice the amount of infection as the checks, and those submerged for one hour at ten feet had four times as much. That length of time of submersion of the potatoes is a factor to consider in the use of handling vats is shown by the difference in infection between one hour and one-half hour at a depth of ten feet. The one-hour treatment resulted in 6.1 percent more infection than one-half hour and inspection of the angle transformations show this difference to be of a significant magnitude.

The depth to which the tubers were submerged in the water was important in respect to subsequent infection. Comparisons of treatments in which the tubers were in the vat for the same length of time show that more infection resulted at ten feet than at either five feet or one foot. The difference in percentage infection resulting between five feet and one foot was practically nil.

Length of time of submersion

To determine approximately how long tubers were likely to remain in bulk handling vats, marked tubers were run through a vat at the Mettler shed at Edison and timed as they appeared on the conveyor belt. The depth of this vat is approximately eight feet, and its capacity is about two truck or trailer loads. The elevator is built into the slope of one side of the tank, with the other walls sloping toward it, as shown above in figure 1.

Ten average size tubers were marked by being stretch-wrapped with pliofilm and were dropped into the corners of the vat away from the elevator as a truck was being unloaded. They appeared on the conveyor belt in the following number of minutes: 6.5, 8.0, 9.0, 10.5, 23.0, 42.0, 42.0, 140.0, 140.0, and 145.0. During this period, packing operations were halted for a five minute rest period, otherwise they were continuous. The two tubers coming out of the vat in 42.0 minutes appeared when the potatoes which had lodged in the corners of the vat were pushed down manually, and the last three tubers appeared only as the vat was cleared of all potatoes at the noon cleanup.

A second run of ten tubers was placed in the vat at the mid-point of the outside wall and with the flow of potatoes from a truck. They emerged onto the conveyor belt in 14.0, 14.5, 15.0, 15.5, 16.0, 17.0, 17.5, 19.0, 81.0, and 85.0 minutes. The latter two came out of the vat at the noon cleanup. This run was repeated again and all tubers were out of the vat in 21 minutes. A fourth run consisted of ten similarly wrapped tubers placed in the corners of the vat as in the first run. These appeared on the conveyor in 9.0, 12.0, 14.0, 40.0, 43.0, 44.0, 50.0, and 50.0 minutes and one tuber was lost. All of these potatoes with the exception of three were stagnated in the vat and did not flow to the elevator until the vat was emptied just prior to the noon shut-down.

It is possible that some tubers remain in this bulk handling vat for considerable time and until the vat is completely emptied. Under the system of operation at this shed, the vat is emptied every four or five hours and it is reasonable to expect that a few potatoes are submerged and held for this length of time.



Discussion

Much of the bacterial soft rot infection found in tubers was at the lenticels and the symptoms described by Smith and Ramsey (8) are in accord with those observed in these tests. Water-soaked and slightly darkened areas around the lenticels appeared first and as infection advanced these areas coalesced so that the individual lenticel infections could not be distinguished (figure 4). The breakdown of the tubers in many instances was rapid and at the time of inspection the decayed tissue had become whitish or creamy, very soft, somewhat watery and even slimy so that surrounding tubers had become wet. The economic importance of this type of decay is considerable. Smith and Ramsey report that bacterial soft rot is the most important cause of decay in carloads requiring reconditioning at the Chicago Produce Terminal, and that the percentage of decay ranged from 2 to 98 percent in the cars examined in 1942. Although no definite relationship was established between the "breakdown" reported and the incidence of soft rot infection in the 1946 shipments from Kern County, it is quite possible that soft rot was the causal factor. The increased infection resulting from submersion of the tubers in these tests indicates that the ordinary amount of infection would be multiplied by the use of vats for bulk handling at the shipping point.

The application of hydrostatic pressure in the laboratory tests had the same effect upon soft rot infection as submerging the tubers in the vat test. In both types of test, the resulting soft rot infection was significantly greater at the simulated and actual depths of ten feet than at the surface. For depth of submersion or pressure to become an important factor the one apparently must be greater than five feet and the other greater than 2-1/2 pounds per square inch. The percentages of tubers infected in the vat test were the same at one and five feet and increased greatly at ten feet. Another factor to consider is length of time during which the tubers are submerged in the vat since those held at ten feet for one hour were more seriously infected than those held at that depth for one-half hour. Likewise, the checks, which were submerged in the vat only long enough to wet the tubers, had considerably less infection than those held at the surface for one hour. The length of the submersion period in these tests may have been exaggerated because many of the tubers came out of the vat at the Mettler shed within an hour; however, it must be remembered that others remained until the vat was emptied at noon.

Since most of the soft rot infection originated at the tuber lenticels, some discussion of the mechanics of the effect of deep water submersion upon infection is in order. Two factors to be considered are the entrance of bacteria and the entrance of water into the lenticels. That bacteria may enter the lenticels is indicated by the work of Smith and Ramsey; they found no lenticel infection in tubers which had been surface sterilized and then submerged in distilled water, whereas tubers which stood in a water suspension of inoculum became infected at the lenticels. Lenticel infection occurs quite often in the field and it seems logical that some

bacteria would become lodged in the lenticels during the growth of the tubers. When the tubers are submerged, water may penetrate the lenticel openings and either provide the necessary moisture for growth of the bacteria already present or carry the inoculum into the lenticels. That deeper penetration of the solution occurs under hydrostatic pressure was demonstrated by immersing tubers in an eosin solution and subjecting them to zero to five pounds pressure per square inch for one hour. Penetration of the dye was determined by slicing off thin layers of the tissue at the lenticels with a razor blade. Dye penetration was noted underneath practically all the lenticel openings of tubers treated with five pounds pressure, but in only a few of the lenticels in tubers receiving zero pounds pressure.

An important consideration in bulk handling is sanitation to avoid an excessive amount of inoculum in the water. The concentration of organisms can be kept at a minimum by a constant fresh supply of water and by periodic cleaning of the vat. No tests on the effects of chlorinating the wash water were made in this study but operators who used this method during the 1947 season reported that it gave satisfactory results.

Recommendations

The results of these studies of the relationship of bacterial soft rot infection to the bulk handling methods used for Kern County potatoes justify the following recommendations for the use of bulk handling vats:

(1) Shallower water depths should be used in the vats. This may be accomplished by redesigning the vats or by using the same vats with less water. It is probable that the potatoes should never be submerged more than five feet below the water surface.

(2) The quantity of tubers dumped into a vat at one time should be small enough to insure immediate movement through the vat and into the elevator. Particular care should be taken to prevent the potatoes from lodging in the corners of the vat and remaining in the water for a considerable period of time. Before shut-downs in operation, such as during the noon hour, it would be advisable to empty the vat of tubers.

(3) Sanitation should be practiced to prevent an accumulation of rot organisms in the vat water. This means that the water should be changed completely at least once each day, and preferably twice or oftener as operations permit. The treatment of the water in the vat with chlorine as practiced by commercial concerns seemed to provide satisfactory sanitation during the 1947 season.

Table 1. The influence of laboratory submerging treatments upon the incidence of bacterial soft rot infection of potato tubers.

<u>Treatment</u>	<u>Mean infection per lot based on</u>	
	<u>Angle</u> ^{1/}	<u>Percentage</u> ^{2/}
<u>tuber counts.</u>		
Uninjured, 0 lbs. pressure	8.50	2.2
5 lbs. pressure	28.83	23.3
Sun injured, 0 lbs. pressure	43.87	48.0
5 lbs. pressure	40.03	41.4
Mechanically injured, 0 lbs. pressure	3.47	0.4
5 lbs. pressure	17.94	9.5
Check (tap water), 0 lbs. pressure	8.00	1.9
Significant difference	3.55	---
Observed F	24.01 ^{3/}	---

1/ Angle = Arc sin $\sqrt{\text{percentage}}$.

2/ Determined from the mean angle.

3/ Odds against the difference noted being due to chance are greater than 99:1.



Table 2. The influence of vat submerging treatments upon the incidence of bacterial soft rot infection of potato tubers.

Shafter, California, 1947.

<u>Treatment</u>	<u>Replication</u>				<u>Mean Infection</u>	
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>Angle 1/</u>	<u>Percentage 2/</u>
(1) 1 hour, Total no. of tubers 1 foot, Percentage of infected tubers	388 8.8	395 6.1	380 11.1	369 7.9	16.84	8.4
(2) 1 hour, Total no. of tubers 5 feet, Percentage of infected tubers	383 5.5	365 9.3	370 12.7	393 6.4	15.86	8.4
(3) 1 hour, Total no. of tubers 10 feet, Percentage of infected tubers	382 11.0	372 29.3	388 10.3	381 17.9	23.97	16.5
(4) 1 1/2 hour, Total no. of tubers 10 feet, Percentage of infected tubers	384 11.2	380 9.0	386 12.4	377 9.3	18.85	10.4
(5) Check, Total no. of tubers Washed only, Percentage of infected tubers	389 3.1	361 3.9	361 5.3	394 5.1	11.97	4.3
Significant difference					2.33	----
Observed F					5.53 ^{3/}	----

1/ Angle = Arc sin $\sqrt{\text{percentage}}$

2/ Determined from the mean angle.

3/ Odds against difference noted being due to chance are greater than 19:1, less than 99:1.

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Figure 1. The interior of the bulk handling vat at the E. H. Mettler potato shed, Edison, California. The conveyor for elevating the tubers from the vat to the grading belt is at the center of the photograph.



Figure 2. Potatoes being dumped into a bulk handling vat from a truck by means of a hydraulic lift. E. H. Mettler Potato Shed, Edison, California.

